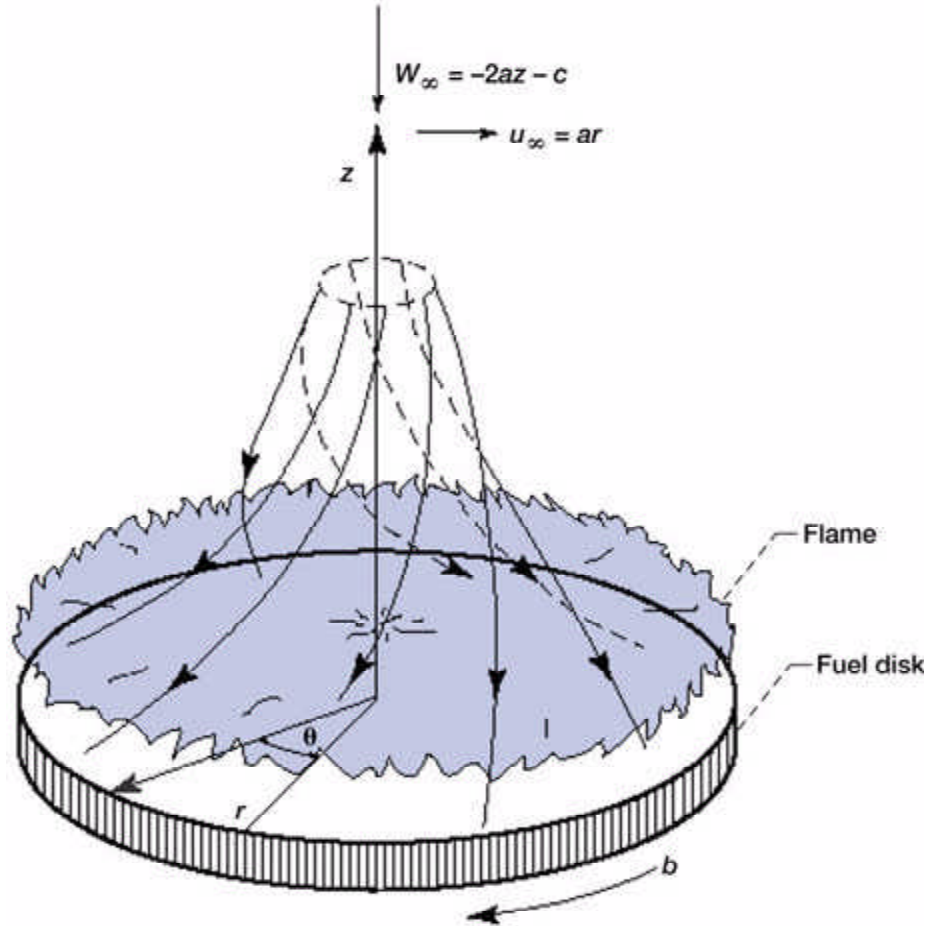


# Dynamics of Diffusion Flames in von Karman Swirling Flows Studied

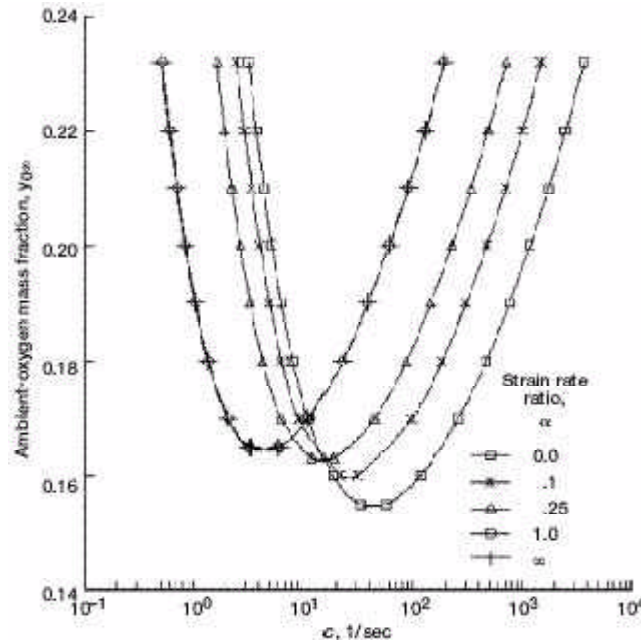


*Von Karman swirling flow with an imposed forces flow, where  $c$  is the combined strain rate  $(a^2 + b^2)^{1/2}$ ,  $a$  is the rotational speed of the disk, and  $b$  is the free-stream strain.*

Von Karman swirling flow is generated by the viscous pumping action of a solid disk spinning in a quiescent fluid media. When this spinning disk is ignited in an oxidizing environment, a flat diffusion flame is established adjacent to the disk, embedded in the boundary layer (see the preceding illustration). For this geometry, the conservation equations reduce to a system of ordinary differential equations, enabling researchers to carry out detailed theoretical models to study the effects of varying strain on the dynamics of diffusion flames. Experimentally, the spinning disk burner provides an ideal configuration to precisely control the strain rates over a wide range.

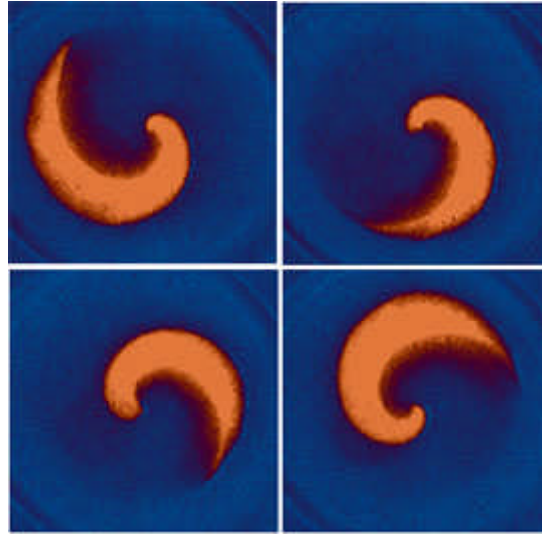
Our original motivation at the NASA Glenn Research Center to study these flames arose from a need to understand the flammability characteristics of solid fuels in microgravity where slow, subbuoyant flows can exist, producing very small strain rates. In a recent work (ref. 1), we showed that the flammability boundaries are wider and the minimum

oxygen index (below which flames cannot be sustained) is lower for the von Karman flow configuration in comparison to a stagnation-point flow. Adding a small forced convection to the swirling flow pushes the flame into regions of higher strain and, thereby, decreases the range of flammable strain rates, as illustrated in the following graph.



*Flammability boundaries for PMMA:  $c$  is the combined strain rate  $(a^2 + b^2)^{1/2}$ , where  $a$  is the rotational speed of the disk,  $b$  is the free-stream strain, and  $\alpha$  is the ratio  $a/b$ .*

Experiments using downward facing, polymethylmethacrylate (PMMA) disks spinning in air revealed that, close to the extinction boundaries, the flat diffusion flame breaks up into rotating spiral flames (refs. 2 and 3). Remarkably, the dynamics of these spiral flame edges exhibit a number of similarities to spirals observed in biological systems, such as the electric pulses in cardiac muscles and the aggregation of slime-mold amoeba. The tail of the spiral rotates rigidly while the tip executes a compound, meandering motion sometimes observed in Belousov-Zhabotinskii reactions. The following figure shows a sequence of false-color images of these spiral flames.



*Typical false-colored images of spiral flames; the fuel disk rotates clockwise and the spiral counter-clockwise.*

Recently, we further explored the pattern-forming regions close to the extinction boundary using a gas-fueled, porous-disk burner (ref. 4). Experiments reveal a rich variety of complex patterns that depend on the fuel flow rate and the disk rotation speed. Theoretical models to describe these observations using activation energy asymptotics are currently underway (ref. 5).

These results will improve the interpretation of turbulent flames and flammability limits. This work is being done at the National Center for Microgravity Research at the NASA Glenn Research Center in collaboration with Prof. Forman Williams from the University of California, San Diego.

## References

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